ARMSTRONG LABORATORY

AL/CF-TR-1996-0134

# THE EFFECTS OF VARIOUS ANTI-G SUIT PRESSURES AND POSITIVE PRESSURE BREATHING ON LUNG VOLUMES AS MEASURED BY SPIROMETRY AT +1 Gz


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JULY 1996

FINAL REPORT FOR THE PERIOD FEBRUARY 1990 TO DECEMBER 1995

Approved for public release; distribution is unlimited

AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6573

# NOTICES



## TECHNICAL REVIEW AND APPROVAL

## AL/CF-TR-1996-0134

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

**FOR THE DIRECTOR**

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**THOMAS J. MOORE, Chief**
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# REPORT DOCUMENTATION PAGE

**Form Approved**
**OMB No. 0704-0188**



| 1, AGENCY USE ONLY (Leave Blank) | 2. REPORT DATE | 3. REPORT TYPE AND DATES COVERED |
|---|---|---|
| | July 1996 | Final - February - 1990 - December 1995 |

**4. TITLE AND SUBTITLE**
The Effects of Various Anti-G Suit Pressures and Positive Pressure Breathing on Lung Volumes as Measured by Spirometry at +1Gz

**5. FUNDING NUMBERS**
PE: 61101F
PR: ILIR
TA: BB
WU: 04

**6. AUTHOR(S)**
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**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
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**8. PERFORMING ORGANIZATION REPORT NUMBER**

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
Armstrong Laboratory, Crew Systems Directorate
Biodynamics and Biocommunications Division
Human Systems Center
Air Force Materiel Command
Wright-Patterson AFB OH 45433-7008

**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
AL/CF-TR-1996-0134

**11. SUPPLEMENTARY NOTES**

**12a. DISTRIBUTION/AVAILABILITY STATEMENT**
Approved for public release; distribution is unlimited

**12b. DISTRIBUTION CODE**

**13. ABSTRACT (Maximum 200 words)**
Anti-G Suits have historically been evaluated using G-tolerance as the primary benchmark of a G-suit's effectiveness. One area which has been overlooked for over fifty years of G-suit design, is the effect of G-suit inflation on lung volumes. Lung inflation to about 75 percent of normal capacity is the key to producing the optimum intrathoracic pressure for performing the anti-G straining maneuver. This study evaluated three separate G-suit designs, at +1 Gz and looked at the effect positive pressure breathing (PPB) had on maintaining lung volumes during G-suit inflations to 4, 6, and 8 psi. Lung volumes were measured using a microprocessor based spirometer. Results showed that the full pressure suit design (APS) had the smallest effect on inspiration. But in a comparsion of the standard G-suit (trousers), the full coverage trousers (ATAGS) proved to be superior in design compared to the standard five bladder suit (CSU-13B/P). At suit pressures of 8 psi, Forced Inspiratory Vital Capacity (FIVC) percent change from baseline values for the APS, ATAGS, and CSU-13B/P were 80, 93, and 60% respectively. When PPB was added, FIVC values were 102, 66, and 46% respectively. These data show that the addition of PPB with anti-G suit trousers becomes a liability to lung function while the full pressure suit condition benefits by the addition of PPB. The use of pulmonary function testing as a means of determining the effect G-suit inflation has on lung volumes may prove to be very useful in designing and evaluating the next generation of anti-G protection ensembles.

**14. SUBJECT TERMS**
Pulmonary Function, Anti-G Suit, Forced Vital Capacity, acceleration protection, Forced Inspiratory Vital Capacity, Lung Volumes, Spirometry, Positive Pressure Breathing

**15. NUMBER OF PAGES**
39

**16. PRICE CODE**

| 17. SECURITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |
|---|---|---|---|
| UNCLASSIFIED | UNCLASSIFIED | UNCLASSIFIED | UNLIMITED |

NSN 7540-01-280-5500
Computer Generated 1996



Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

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## PREFACE

This work was completed under PROJECT/TASK/WORKUNIT ILIRBB04 The research was conducted in the Combined Stress Branch (AL/CFBS), Biodynamics and Bioengineering Division, Crew Systems Directorate, Armstrong Laboratory, Wright Patterson AFB, OH.

The authors wish to express their appreciation to Mr. Steve Bolia for assembling the positive pressure breathing and G-valve systems and his advice and support throughout this study, to the nine men and women who volunteered as test subjects for this study and gave this effort 100 percent support despite the high degree of discomfort produced by the anti-G suit at 8 psi at 1.0 Gz.

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# INTRODUCTION

Research into the development of advanced anti-G suits for the USAF has increased in pace over the past 10 years. New advanced G-suit designs include both pneumatic and water filled counter pressure designs. The addition of positive pressure breathing for G (PBG) has been shown to provide a greater increase in human G-tolerance (1, 2, 3). PBG is currently being used operationally in both the F-16 and F-15 aircraft to augment the current standard anti-G suit protection system (4). To date, the efficacy of new G-suit designs has been measured in terms of the wearers' ability to maintain eye level blood pressure during high sustained G exposure. This approach to G-protection validation addresses only one side of the cardiopulmonary interaction that is involved with maintaining consciousness during flight. The maintenance of adequate oxygen exchange within the lungs is an important element in maintaining cognitive and physical well being during an air-to-air combat engagement (5). In a review of the literature, on the effect of gravity and acceleration on the lung, Glaister describes the cumulative effects of G-forces as low as +4 and +5 Gz have on arterial oxygen desaturation. Gliaster also noted that oxygen desaturation was more pronounced when the anti-G suit was worn (protected) compared to the no G-suit condition (unprotected).

Although G-endurance testing of new anti-G suit designs has provided a plethora of data to the aeromedical literature over the years, little has been done to minimize the mechanical effects of G-suit inflation on the pulmonary system as part of the design process. Mechanical limitations of these suits are primarily centered around the abdominal bladder and its effect on impeding the downward movement of the diaphragm during inspiration. Another respiratory limitation resulting from G-suit inflation involves the constriction of the lower rib cage during inspiration. Circumferentially applied pressure in this area prevents full ribcage expansion making inspiration extremely difficult (6, 7, 8). Similar findings have been seen in the application of pneumatic anti-shock trousers (9, 10, 11, 12).

From a G-protection stand point, the abdominal bladder plays an integral part of the total G-protection system. In work by Wood and Lambert (13), the effect of independently inflating leg and abdominal sections of the G-suit on relaxed +Gz tolerance was investigated. Results from this study showed an increase in relaxed G tolerance of 1.2 G with total suit inflation, 0.6 G increase with abdominal bladder inflation only, and a 0.2 G increase with leg bladder inflation. These data were later confirmed by Burton and Krutz, who demonstrated a 1.2 G total relaxed tolerance and 0.2 G increase in relaxed tolerance when legs were inflated, 0.7 G increase with abdominal inflation, and 0.3 G increase with the G-suit donned and no inflation (14). Current anti-G suit designs have not addressed these issues; nor has the resolution of pulmonary effects of anti-G suit inflation been studied.

It is not the purpose of this paper to advocate the elimination of the abdominal bladder from current advanced G-suit designs, but instead, to offer an additional means of evaluating the mechanical effects of abdominal bladder on lung volumes during G-suit inflation.

The following describes 1 Gz pulmonary function evaluations performed on subjects wearing various G-protective ensembles. Each G-suit condition was evaluated with and without positive pressure breathing at G-suit pressures of 4, 6, and 8 psi.

## METHODS

Subjects: Nine centrifuge test subjects, three female and six male participated in this study after having given informed consent. Subjects were members of the sustained acceleration test stress panel of the Combined Stress Branch, Armstrong Laboratory, Wright-Patterson AFB, OH. All subjects completed an extensive physical examination screening prior to their inclusion into the test subject pool. Subjects ranged in age from 23 to 38 years, mean age 28. All subjects met the current Air Force minimum height requirements for flying of 64 inches as prescribed in AFI 48-123. None of the nine subjects had a previous or current smoking history.

Equipment: Subjects wore the standard issue flight suit, boots, G-protective systems used in this study included: Standard issue CSU 13-B/P, Advanced Protection Anti-G Suit (APS) and the Advanced Technology Anti-G Suit (ATAGS), Appendices A through F. In addition, subjects wore various components (oxygen mask, counter pressure vest, and helmet) or the full Combined Advanced Technology Design G Ensemble (COMBAT EDGE). Subjects were instrumented with a 3 lead electrocardiogram, or ECG. Each of the six G-suit and three pressure conditions were randomized across subjects to reduce the occurrence of order effects. Subjects were seated in a Martin Baker F-4 seat with seat back angle reclined 13 degrees from the vertical and secured in place with a Teledyne® quick release lap belt system. In addition, subjects wore a Gentex® (Carbondale IL) HGU-55/P helmet and modified Gentex MBU-12/P (Gentex Mask Division Pomona CA) aviators oxygen mask. Appendix G, shows the modified oxygen mask with two separate air hoses, one hose was connected to the breathing regulator via a CRU-60 or Integrated Terminal Block (ITB), and a second hose which was connected to a spirometer. A Spirometrics model 2500 (Spirometrics Inc. Auburn, ME) microprocessor based spirometer was used to measure both inspiratory and expiratory phases of pulmonary function test. A Bellofram G-valve (consisting of two sets of electronic solenoid valves) were used to generate G-suit pressure while the positive pressure supplied to the mask was supplied by a Litton Industries CRU-93 breathing regulator. An Omega (Omega Engineering Stamford, CT) model (PX142-015 G 5V) 0-15 psi pressure transducer measured suit pressures while an Omega model (PX142-005 G 5V) 0-5 psi pressure transducer measured mask pressure levels. Mask pressure, G-Suit pressure, and pulmonary function data were collected and stored on a Zenith 248 microcomputer. Appendix H, shows an overview of the laboratory set-up.

Procedures: After donning a flight suit, boots, and one of the six G-protection combinations, subjects were seated in a Martin Baker aircraft seat and secured in place with a lap belt and the G-suit pressure supply hose was connected into the G-valve pressure supply hose. A flight helmet was donned and the oxygen mask secured snugly to the face via helmet bayonet system. It was important at this point for the subject to seal their lips around the mouth piece mounted inside the oxygen mask. The oxygen mask was then connected to a CRU-93 breathing regulator in which

the positive pressure breathing mode could be selected. A fit test was accomplished once the subject's oxygen mask was in place. This final oxygen mask pressurization check prior to the start of the experiment allowed investigators time to make adjustments to the mask and to resolve any air leaks.

Pulmonary function tests were accomplished prior to, during, and again following anti-G suit inflation to either 4, 6, or 8 psi for a duration of 1 minute. Near the end of the 1 minute exposure the subject pinched off the air flow to the nose via the valsalva port on the soft shell area of the oxygen mask (preventing airflow through the nose while performing the pulmonary function test) then prepared to begin the pulmonary function test. The PFT was accomplished by having the subjects perform a maximal inhalation, seal their lips around the mouth piece of the spirometer, then forcefully exhale. The exhalation phase lasted for 6 seconds. During the exhalation phase, subjects were coached to ensure that a maximal exhalation effort was exerted. The exhalation phase was followed by having the subjects perform a maximum inhalation thus completing the respiratory cycle. Pulmonary function measures obtained during testing included forced vital capacity (FVC), forced expiratory volume at one second (FEV1), and forced inspiratory vital capacity (FIVC). All pulmonary functions values described in this report are represented as percent change of pre baseline data.

## RESULTS

Analysis: An ANOVA was accomplished to discover main effects in FVC, FEV1, and FIVC. Level of significance was set at $p \leq 0.05$. Post-hoc analysis using a paired-t test was accomplished comparing pre-baseline PFT values and suit inflation PFT values. There were no significant changes when comparing pre-baseline data to other baseline data. Pulmonary function test values were evaluated as percent of pre-baseline.

Results: Significant changes in FVC were observed at suit pressure of 4 psi. ATAGS with PBG was significantly different from the standard suit and standard with PBG. These data are illustrated in (Appendix I). The APS suit showed no significant effect on FVC during the 4 psi suit inflation condition. A 15.7% decrease in FVC was seen in the standard suit compared to the ATAGS suit condition. At 6 psi, one significant change was observed in the APS with PBG and standard suit comparison with the standard suit condition showing a 17.5% decrement (see Appendix I).

Eight psi suit pressures showed the most interesting results in the area of PBG application. Increases were seen in vital capacities when comparing APS to APS with PBG and the standard suit to the standard suit with PBG, showing an increase of 11 and 25 percent of pre-baseline respectively. Appendix I, illustrates these findings. A 22 and 31 percent decrement were seen in the APS compared to the STD and APS with PBG and STD suit conditions respectively. In the operational context of a pilot performing the anti-G straining maneuver the usefulness of FVC data at 6 seconds becomes less important from an aeromedical standpoint.

A more interesting piece of information may be what is the amount of air that can be moved from the lungs in 1 second or forced expiratory volume in one second or (FEV1). These data are more indicative of the effects of G-suit inflation on exhalation while performing the exhalation phase of the anti-G straining maneuver. The FEV1 value can be derived from the FVC chart at the one second point from the start of expiration Figure 1.

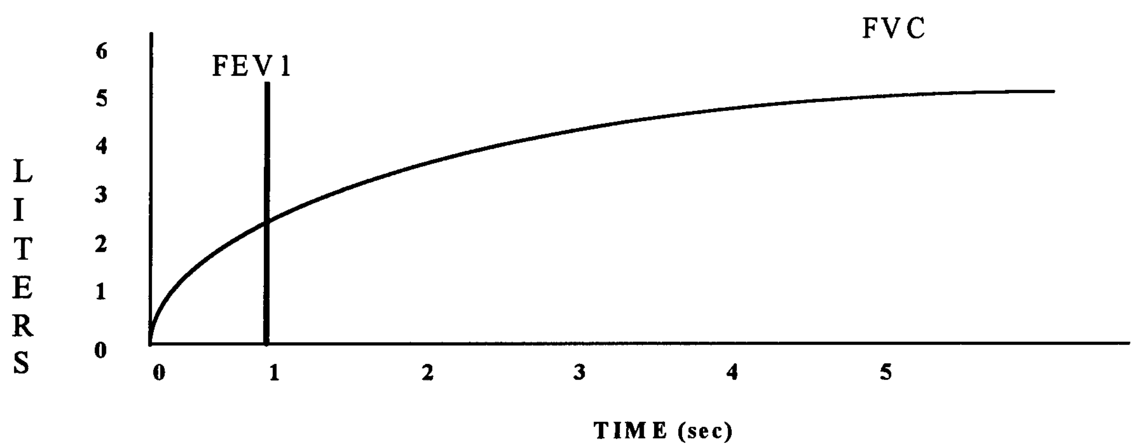



Figure 1. An Example of a Volume Time Curve.

The reason this information has more impact on the operational pilot is that the anti-G straining maneuver requires the pilot to force air from the lungs then to force air back into the lungs in a very short period of time (within 1 to 2 sec). Appendix J illustrates the shortcomings of the standard suit both with and without PBG.

The number of suit and pressure combinations statistically different from one another were minimal at G-suit pressures of 6 psi level. Appendix J shows the APS and ATAGS data with PBG compared to the Standard suit with PBG with a 24 and 31 percent change from pre-baseline respectively.

The most significant decreases in FEV1 at G-suit pressures of 8 psi were in the standard suit with PBG condition when compared to APS, ATAGS and ATAGS with PBG. There was an increase in FEV1 in the standard suit with PBG compared to the standard suit only. Appendix K, illustrates these data. The ability to inhale is important in delivering an effective straining maneuver. Appendicies I and J, represent the statistically significant changes seen in Forced Inspiratory Vital Capacity (FIVC) at 4, 6, and 8 psi.

The forced inspiratory volume measure can be likened to the inspiratory phase of the anti-G straining maneuver in that at end-expiration, the subject then inhales quickly (within 1-2 seconds). During the performance of the straining maneuver, however, the subject holds his or her breath for 3 to 5 seconds. The ability to reinflate the lungs is a key component of an anti-G straining

maneuver, because of the heavy reliance on intrathoracic pressure to the great vessels of the heart which is vital in maintaining eye level blood pressure during high G maneuvering. At 4 psi there is a minimal effect of suit pressure on the subject's ability to inhale, particularly in the CSU-13B/P anti-G suit.

Suit pressures, greater than 4 psi demonstrate a more dramatic effect of G-suit inflation on a subject's ability to inflate their lungs. Compared to an already compromised inspiratory volume measure in of the APS and ATAGS suit conditions, the standard suit with PBG showed consistently lower inspiratory volumes compared to the other suit conditions.

The most profound effects of G-suit inflation on FIVC occurred at 8 psi. The most severe effects were associated with the application of PBG. This was true not only in the standard suit conditions, with a 40 percent decrease in inspiratory capacity, but also for the ATAGS G-suit without positive pressure compared to ATAGS with PBG which showed a 27% decrease in FIVC. Appendices L through T represent the changes from pre-baseline for values for FEV1, FIVC, and FVC at 4, 6, and 8 psi. In the APS suit condition subjects LE, AD, WH, HU, and DE, could not perform the inspiration phase of the PFT in at least one of the three G-suit pressures. In the APS suit condition, all failures to perform the inspiratory phase of the PFT occured at 8 psi in the PPB condition with the exception of subject LE. This same subject failed to complete the APS with no PPB condition at 4 psi. Subject NE left the experiment and did not complete APS without PPB or the ATAGS with PPB conditions.

Four subjects HU, NE, SM, and KN were unable to perform the inhalation phase of the PFT in the ATAGS with PPB suit condition during moderate to high G-suit inflation pressures. This may be related to a shift in counter pressure vest and G-suit abdominal pressure during exhalation resulting in the downward movement of the diaphragm during inspiration.. Subject WH, could not complete the inspiratory phase of the ATAGS with no PPB condition because a poor fitting G-suit applied pressure to the lower thoracic area causing pain on inspiration. When interviewed after each days series of tests, subjects reported no problems in performing any phase of the pulmonary function test in any of the G-suit conditions with or without PPB.

Appendix U illustrates the percent change from pre-baseline in the various lung volume measures across all subjects.

## DISCUSSION

This study demonstrated how the influence of G-protective system design influences respiratory function. A review of the acceleration research literature show several references to the effect of G-suit abdominal bladder inflation on the respiratory system (5, 15, 16,17). It would appear from the literature that the abdominal bladder is a well documented design limitation. There exist little or no information concerning the attenuation of this problem. Only recently with the development of the ATAGS anti-G suit has a smaller abdominal bladder been proposed to be implemented into

operational equipment. The development of the ATAGS has not included a comparison of the effect of abdominal bladder inflation on the respiratory system with and without PBG. The change in abdominal bladder height was based more on subjective input and not from physiological data.

The inclusion of women into tactical fighter aircraft poses a significant challenge to the life support community to provide well fitting anti-G protective equipment. The problem of poorly fitting equipment for women has been reported on by Ripley, Solnae, and Hill (8). This work showed problems associated with abdominal bladder fit for women who were wearing the properly sized anti-G suit based on height and weight requirements. One problem identified was that the top portion of the CSU-13B/P abdominal bladder was found to be too high and actually covered the lower portion of the rib cage in some subjects.

This caused subjects to experience difficulty in breathing during G-suit inflation. A 2 inch reduction in abdominal bladder height resolved this problem without compromising G tolerance. Of the 28 women pilots evaluated, only 14% reported problems with the abdominal bladder causing pain. It is important to also note that of this same group, 50% were wearing G-suits in which the abdominal sections could not be adjusted to provide a proper fit (8).

The APS system faired the best in our investigation of lung volume changes during suit inflation. One reason for this may be the bladder design of the full pressure suit compared to the multi-bladder design of the CSU-13B/P and ATAGS suits. A full pressure suit design does have its limitations in terms of thermal load and in ease of donning, however. From an operational and physiological standpoint, our study has shown the ATAGS and APS suits to be less taxing physiologically when compared to the CSU-13B/P. Suits with shorter abdominal bladder height have faired well when compared to the standard suit. Tripp and Johnston (18), reported on work involving the Retrograde Inflation Anti-G Suit (RIAGS). In addition to the direction of suit inflation, (foot to head), the abdominal bladder height was 1.5 inches shorter when compared to a comparable size CSU-13B/P. G-endurance tests using a continuous +4.5 to +7 Gz Simulated Aerial Combat Maneuver (SACM) profile showed the RIAGS provided the subject with an additional 145 seconds of G endurance when using the RIAGS alone compared to the CSU-13B/P. The level of G-protection provided by the RIAGS was also illustrated by the preservation of arterial oxygen saturation compared to the levels seen in the CSU-13B/P (19). It can be speculated that preservation of %SaO2 to some degree may be related to the subject's ability to perform a less attenuated respiration cycle when wearing the RIAGS suit.

The ability to complete the inspiratory phase of the anti-G straining maneuver is crucial in providing increased intrathoracic pressure which, in turn, increases transmural pressure on the great vessels and heart. This increase in pressure can be further translated into an increase in eye level blood pressure which is used to protect pilots from the hydrostatic column effects of +Gz acceleration. A review of the forced inspiratory volume data (Appendix L) shows that the CSU-13B/P both with and without PBG had the most profound effect on inspiratory volumes at G-suit pressures of 8 psi. Incorporating these data into the intrathoracic model described above one would predict that lower intrathoracic pressures would result from decreased lung volumes. In fact, Cote et al., (20), defined the relationship between lung volume and transmural intrathoracic

pressure when they evaluated target lung volumes of 12.5, 25, 37.5, 50, 75, and 100 percent of inspiratory volume in-subjects. Results from this study showed that 75 to 85 percent of maximum inspiratory volumes are optimum for generating the maximum intrathoracic pressure and that lower or higher volumes were related to lower intrathoracic pressures (20). Figure 2 illustrates graphically the inspiratory changes from pre baseline for the various anti-G suit conditions.

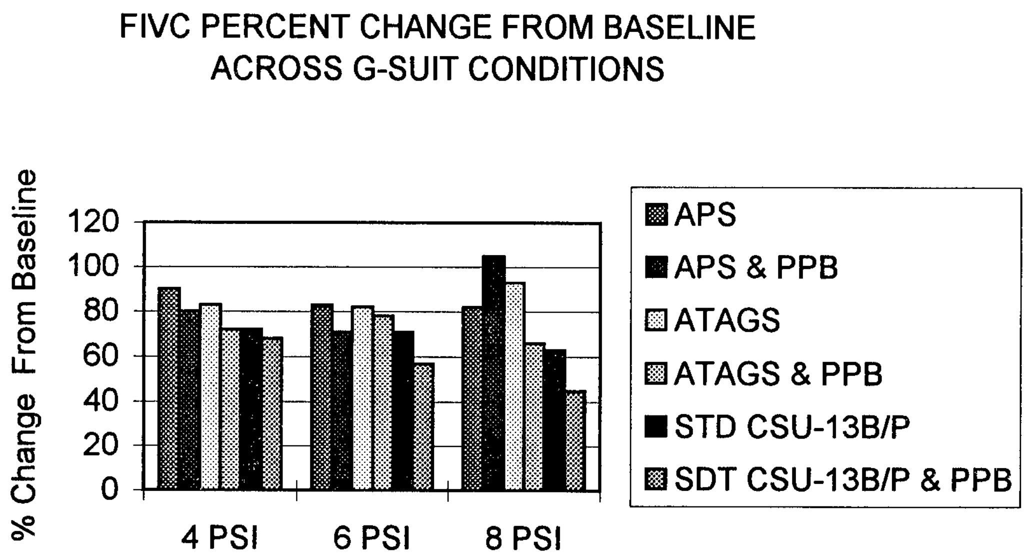



Figure 2. Percent Change From Baseline Forced Inspiratory Vital Capacity for APS, ATAGS, and CSU-13B/P.

Some factors which drive the decrease in inspiratory and expiratory volumes include: +Gz acceleration, G-suit inflation, and restricted chest expansion. In this discussion, we will concentrate primarily on the issues concerning the later two factors. The decrease in respiratory function secondary to G-suit inflation has been recognized as a problem for the aerospace community since 1957, when Bondurant et al. (21) demonstrated a 500 cc decrease in functional residual capacity with G-suit pressure of 103 mm Hg (about 2 psi). In 1970, Espinosa (10) documented changes in vital capacity (VC) with inflation of the G-suit to pressures of 20-30 mm Hg (less than one psi). Inflation of the G-suit to these low pressures yielded a change in VC of 17% (10).

The mechanical properties associated with these changes appear to be directly related to the effect of the abdominal bladder on the position of the diaphragm. Riou et al., (11), inflated military anti-shock trousers on subjects to pressures of 60 to 80 mm Hg at 1 G. Subjects underwent computerized tomography in both a uninflated control and during suit inflation. Results showed the cephaled shift of the diaphragm which reduced the right and left lung height 14 and 8 mm

respectively (11). From these results one might speculate that as abdominal pressure increased so, too, would the degree of compression of the lower lung fields. This would be of great importance during G-suit inflation as the maximum operating pressure of the ALAR Hi-Flow PPB anti-G valve is 13 psi in standard Air Force and Navy aircraft.

Pulmonary function results from the current study demonstrated an individualized respiratory response for each of the three anti-G suits evaluated. Subjects experienced the most difficulty breathing when using the Standard CSU-13B/P suit. This was most likely due to the height of the abdominal bladder impeding on the downward deflection of the diaphragm and by restricting the expansion of the lower half of the rib cage upon inspiration. Appendix A. illustrates this point with a subject wearing the CSU-13B/P while seated in an aircraft seat reclined to 12 degrees. The effect of the ATAGS on respiration was less dramatic when compared to the CSU-13B/P anti-G suit. One reason for this may be related to the shorter abdominal bladder height. This can be seen in Appendix E. The APS suit, a full pressure suit, demonstrated the least effect on respiration. Unlike the bladder configuration of the ATAGS and CSU-13B/P G-suits, the single bladder of the APS provides a more equal distribution of pressure across the body which eliminates pressure points typically associated with classical G-suit design. These operational limitations may be attenuated or eliminated in future G-suit design by evaluating prototype anti-G suits for design limitations which may restrict respiration in the operational setting.

## CONCLUSIONS

This study has demonstrated what profound effects G-suit design has on lung volumes as measured by spirometry. In addition, these data indicated that the CSU-13B/P had the most dramatic effect on lung volumes followed by the ATAGS and the APS suits respectively. The addition of PPB was not an effective countermeasure in decreasing the effect of anti-G suit inflation on lung volumes for the CSU-13B/P or ATAGS at the higher suit pressures. This study also demonstrated the usefulness of pulmonary function testing (PFT) as an effective means of evaluating the pulmonary effects of various anti-G suit designs.

With the introduction of women into fighter aircraft and the differences in anthropometric differences between men and women, the PFT approach may become an important addition to the development of the next generation of anti-G protective garments for the tactical flying community.

# APPENDIX A
## CSU-13B/P Anti-G Suit

# APPENDIX B
CSU-13B/P Anti-G Suit and PPB

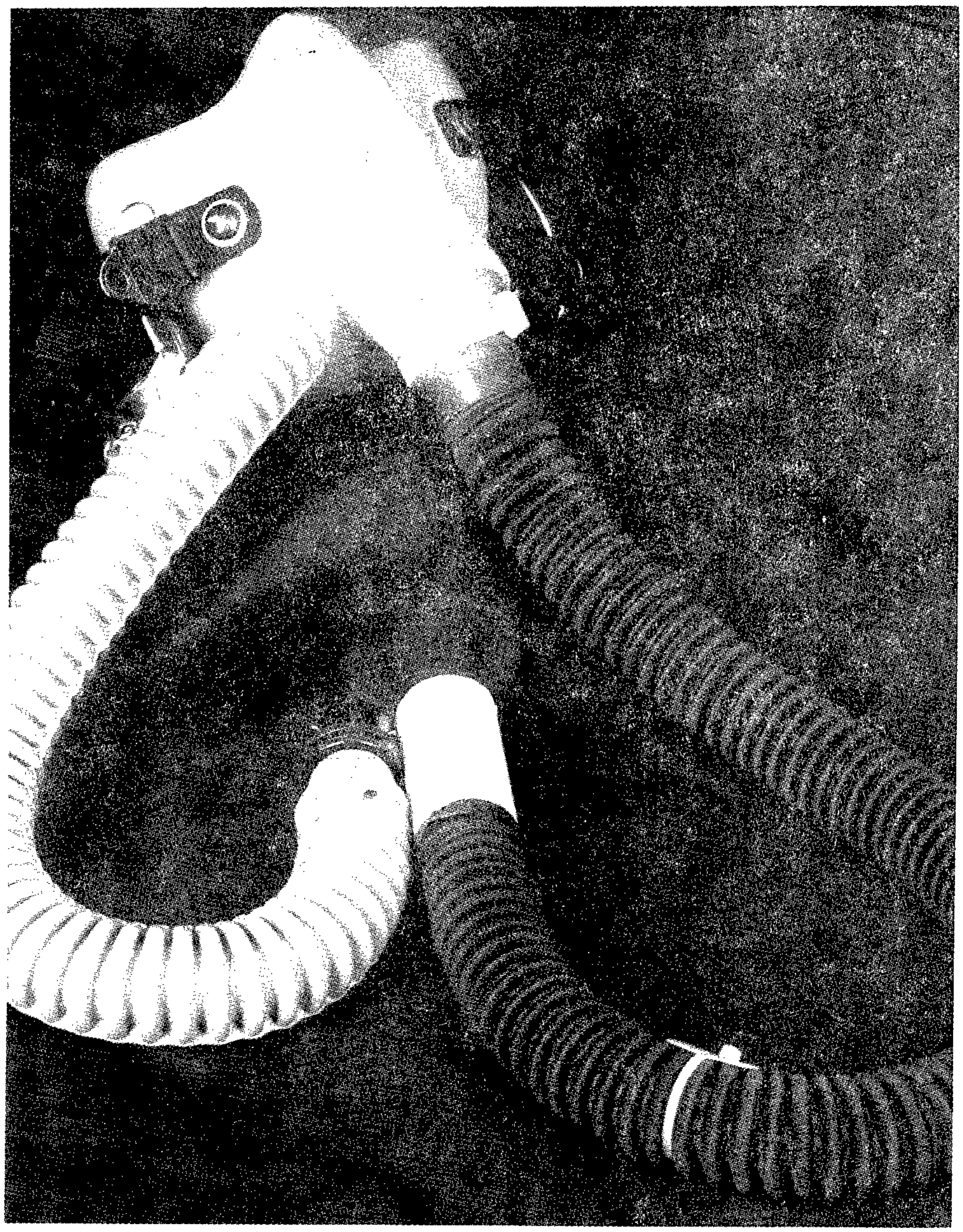
APPENDIX C
Advanced Protection Anti-G Suit (APS)

APPENDIX D
Advanced Protection Anti-G Suit With PPB

APPENDIX E
ATAGS Anti-G Suit

APPENDIX F
ATAGS Anti-G Suit With PPB

APPENDIX G
Modified MBU-12P Oxygen Mask



APPENDIX H

| PERCENT OF PRE-BASELINE FORCED VITAL CAPACITY SUIT PRESSURE 4 psi | | | | | | |
|---|---|---|---|---|---|---|
| Suit Level 1 | Suit Level 2 | Mean Level 1 | Mean Level 2 | Mean Difference | n Size | p-value |
| ATAGS/PBG | STD | 91.8 | 76.1 | -15.7 | 9 | 0.0368 |
| ATAGS/PBG | STD/PBG | 91.8 | 79.1 | -12.6 | 9 | 0.0301 |

| PERCENT OF PRE-BASELINE FORCED VITAL CAPACITY SUIT PRESSURE 6 psi | | | | | | |
|---|---|---|---|---|---|---|
| Suit Level 1 | Suit Level 2 | Mean Level 1 | Mean Level 2 | Mean Difference | n Size | p-value |
| APS & PBG | STD | 93.88 | 76.34 | 17.53 | 9 | 0.0376 |

| PERCENT OF PRE-BASELINE FORCED VITAL CAPACITY SUIT PRESSURE 8 psi | | | | | | |
|---|---|---|---|---|---|---|
| Suit Level 1 | Suit Level 2 | Mean Level 1 | Mean Level 2 | Mean Difference | n Size | p-value |
| APS | APS & PBG | 79.69 | 90.69 | 11.00 | 8 | 0.0298 |
| APS | STD | 79.69 | 57.50 | -22.18 | 8 | 0.0158 |
| APS & PBG | STD | 87.85 | 57.02 | -30.83 | 9 | 0.0005 |
| STD | STD & PBG | 57.02 | 82.68 | 25.65 | 9 | 0.0009 |

## APPENDIX I

### PERCENT OF PRE-BASELINE FORCED EXPIATORY VOLUME IN 1 SECOND SUIT PRESSURE 4 psi

| Suit Level 1 | Suit Level 2 | Mean Level 1 | Mean Level 2 | Mean Difference | n Size | p-value |
|---|---|---|---|---|---|---|
| APS | STD & PBG | 86.57 | 67.57 | -19.00 | 7 | 0.0360 |
| APS & PBG | ATAGS | 108.69 | 83.54 | -25.24 | 9 | 0.0360 |
| APS & PBG | STD | 108.69 | 76.55 | -32.13 | 9 | 0.0366 |
| APS & PBG | STD & PBG | 108.69 | 68.20 | -40.49 | 9 | 0.0058 |
| ATAGS | STD & PBG | 83.45 | 68.20 | -15.24 | 9 | 0.0091 |
| ATAGS & PBG | STD & PBG | 93.25 | 68.20 | -25.05 | 9 | 0.0006 |

### PERCENT OF PRE-BASELINE FORCED EXPIATORY VOLUME IN 1 SECOND SUIT PRESSURE 6 psi

| Suit Level 1 | Suit Level 2 | Mean Level 1 | Mean Level 2 | Mean Difference | n Size | p-value |
|---|---|---|---|---|---|---|
| APS & PBG | STD & PBG | 90.53 | 65.94 | -24.59 | 9 | 0.0340 |
| ATAGS & PBG | STD & PBG | 97.57 | 65.94 | -31.62 | 9 | 0.0238 |

APPENDIX J

| PERCENT OF PRE-BASELINE<br>FORCED EXPIRATORY VOLUME IN 1 SECOND<br>SUIT PRESSURE 8 psi | | | | | | |
|---|---|---|---|---|---|---|
| Suit Level 1 | Suit Level 2 | Mean Level 1 | Mean Level 2 | Mean Difference | n Size | p-value |
| APS | STD & PBG | 81.62 | 57.08 | -24.53 | 8 | 0.0078 |
| ATAGS | STD & PBG | 93.32 | 57.22 | -36.10 | 9 | 0.0254 |
| ATAGS & PBG | STD & PBG | 73.80 | 55.66 | -18.14 | 8 | 0.0399 |
| STD | STD & PBG | 57.22 | 67.72 | 10.49 | 9 | 0.0253 |

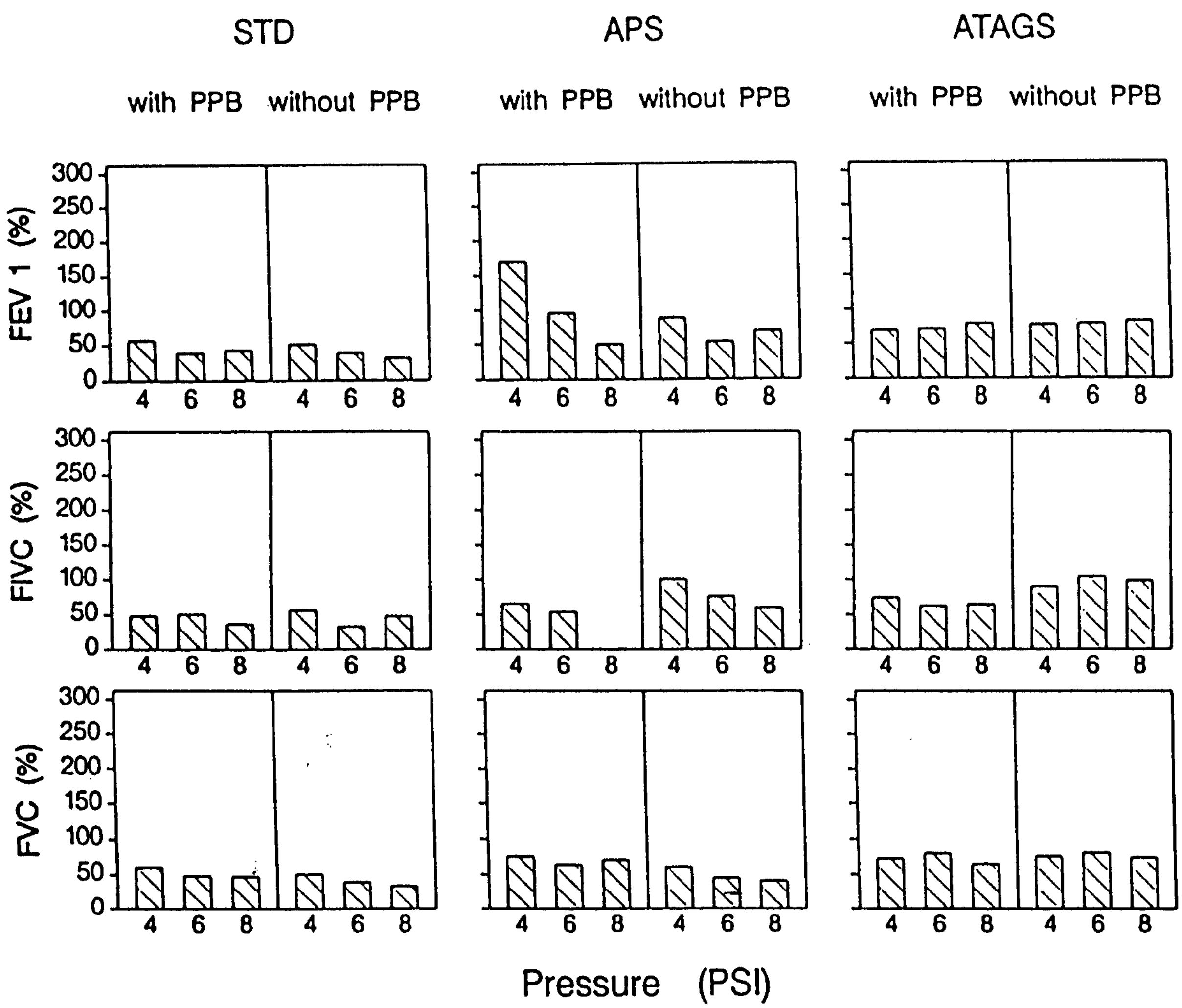
| PERCENT OF PRE-BASELINE<br>FORCED INSPIRATORY VOLUME<br>SUIT PRESSURE 4 psi | | | | | | |
|---|---|---|---|---|---|---|
| Suit Level 1 | Suit Level 2 | Mean Level 1 | Mean Level 2 | Mean Difference | n Size | p-value |
| ATAGS | STD | 82.27 | 72.56 | -10.77 | 9 | 0.0322 |
| ATAGS | STD & PBG | 83.27 | 68.25 | -15.07 | 9 | 0.0279 |

# APPENDIX K

| PERCENT OF PRE-BASELINE FORCED INSPIRATORY VOLUME SUIT PRESSURE 6 psi | | | | | | |
|---|---|---|---|---|---|---|
| Suit Level 1 | Suit Level 2 | Mean Level 1 | Mean Level 2 | Mean Difference | n Size | p-value |
| APS | STD & PBG | 82.39 | 57.393 | -25.0 | 7 | 0.0016 |
| APS & PBG | STD & PBG | 74.38 | 57.393 | -16.99 | 7 | 0.0298 |
| ATAGS | STD & PBG | 84.80 | 57.393 | -27.40 | 7 | 0.0112 |
| ATAGS & PBG | STD & PBG | 78.57 | 57.654 | -20.91 | 6 | 0.0139 |

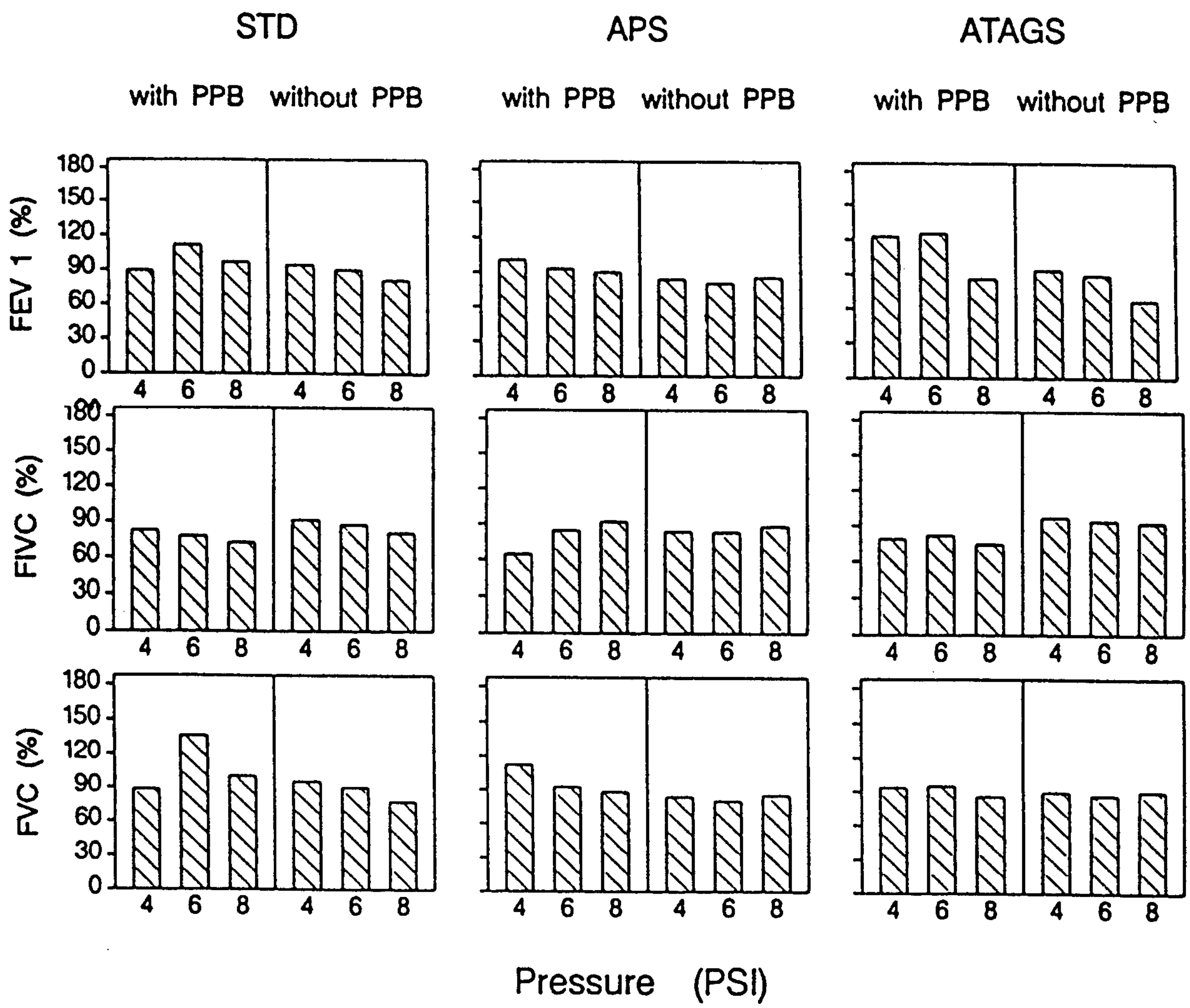
| PERCENT OF PRE-BASELINE FORCED INSPIRATORY VOLUME SUIT PRESSURE 8 psi | | | | | | |
|---|---|---|---|---|---|---|
| Suit Level 1 | Suit Level 2 | Mean Level 1 | Mean Level 2 | Mean Difference | n Size | p-value |
| APS | STD | 80.24 | 60.66 | -19.57 | 8 | 0.0043 |
| APS | STD & PBG | 78.98 | 45.81 | -33.17 | 5 | 0.0200 |
| APS & PBG | STD | 102.10 | 67.02 | -35.08 | 5 | 0.0413 |
| ATAGS | ATAGS & PBG | 93.47 | 66.42 | -27.05 | 5 | 0.0008 |
| ATAGS | STD | 82.96 | 60.41 | -22.55 | 8 | 0.0136 |
| ATAGS | STD & PBG | 85.45 | 45.81 | -39.64 | 5 | 0.0054 |

Appendix L
Percent of Pre Baseline for Each G-suit Condition at 4, 6, and 8 psi
Subject AD



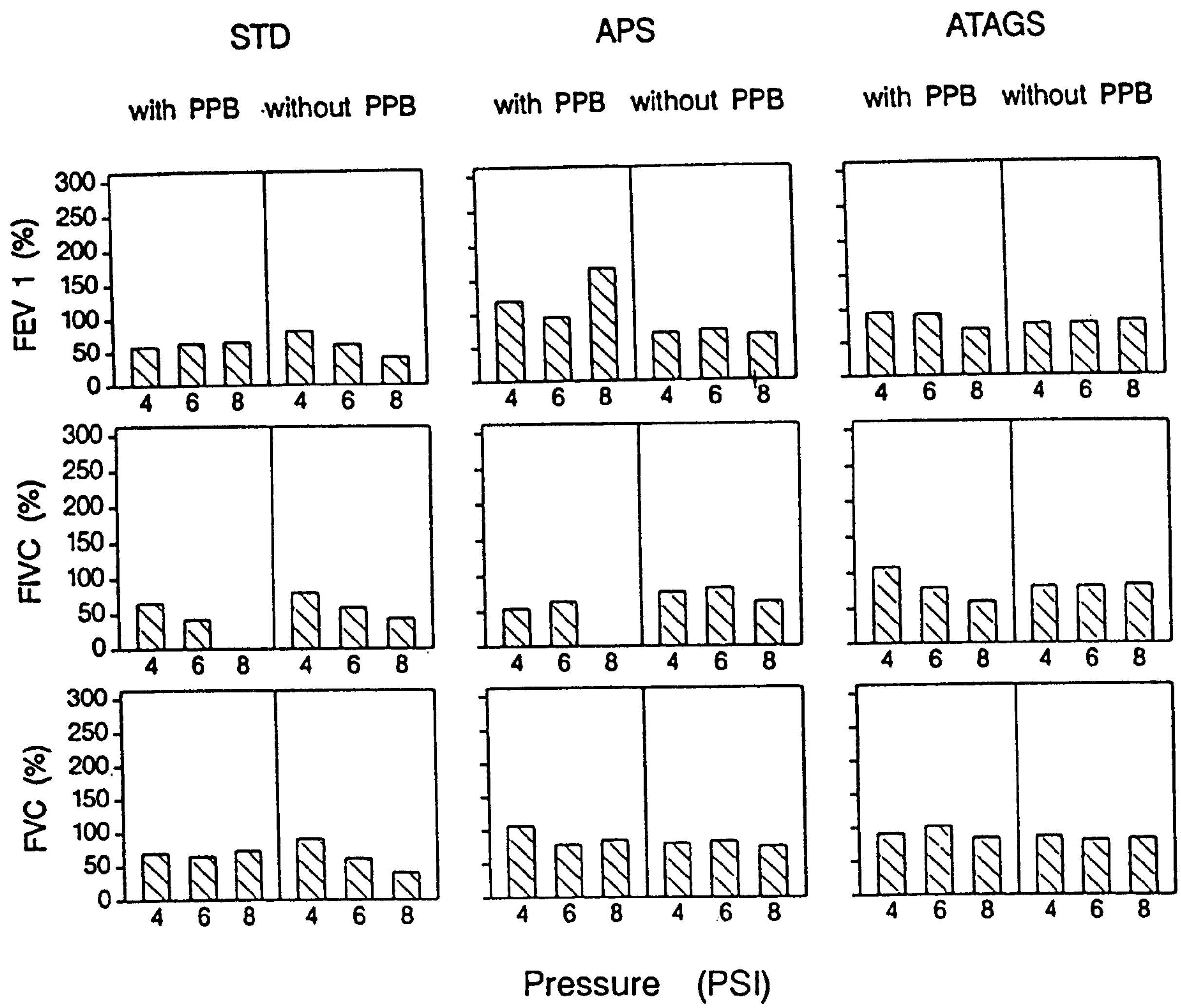

AD
Data is percent of Pre-Baseline

Appendix M
Percent of Pre Baseline for Each G-suit
Condition at 4, 6, and 8 psi
Subject CO



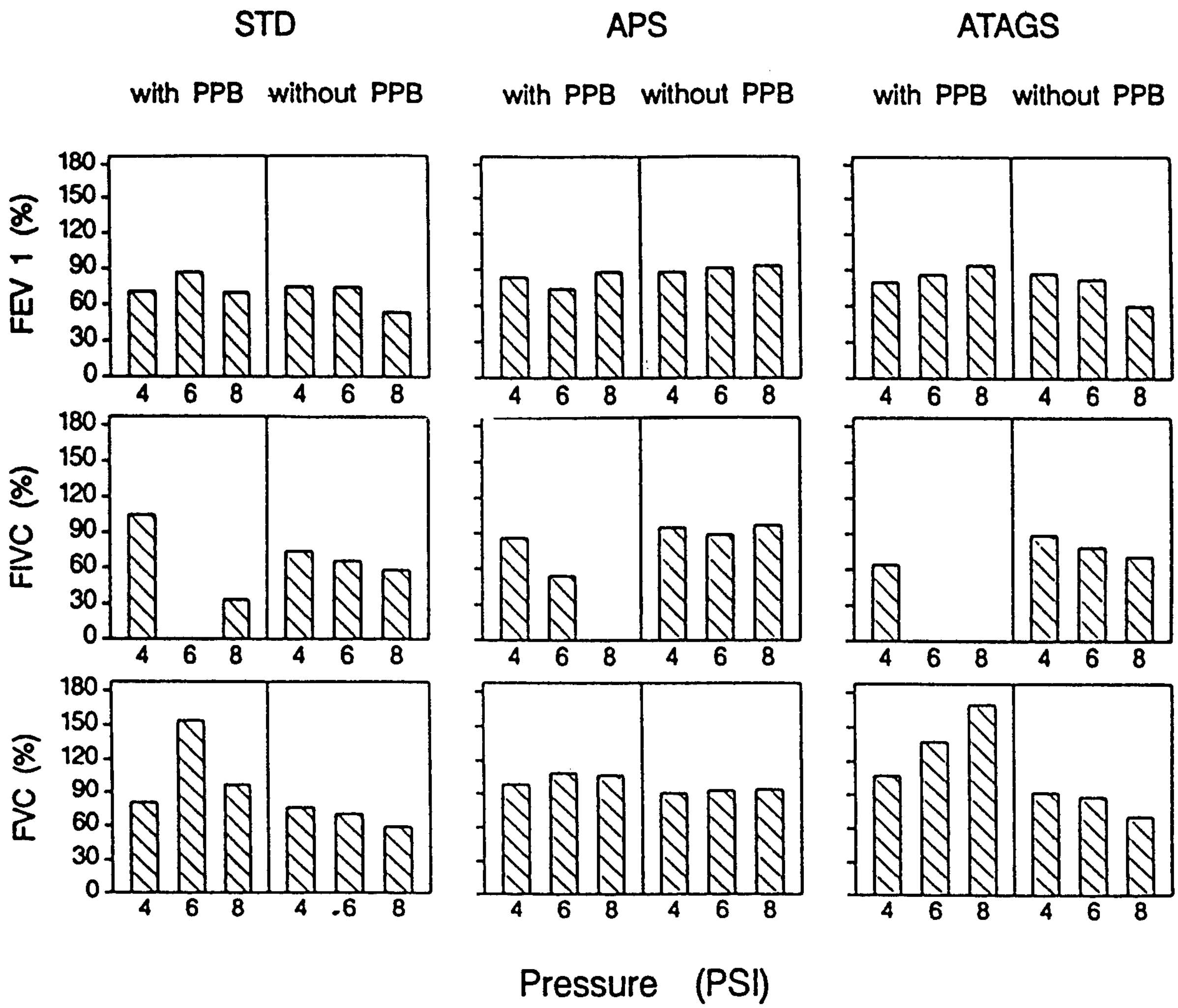

CO
Data is percent of Pre-Baseline

Appendix N
Percent of Pre Baseline for Each G-suit Condition at 4, 6, and 8 psi
Subject DE



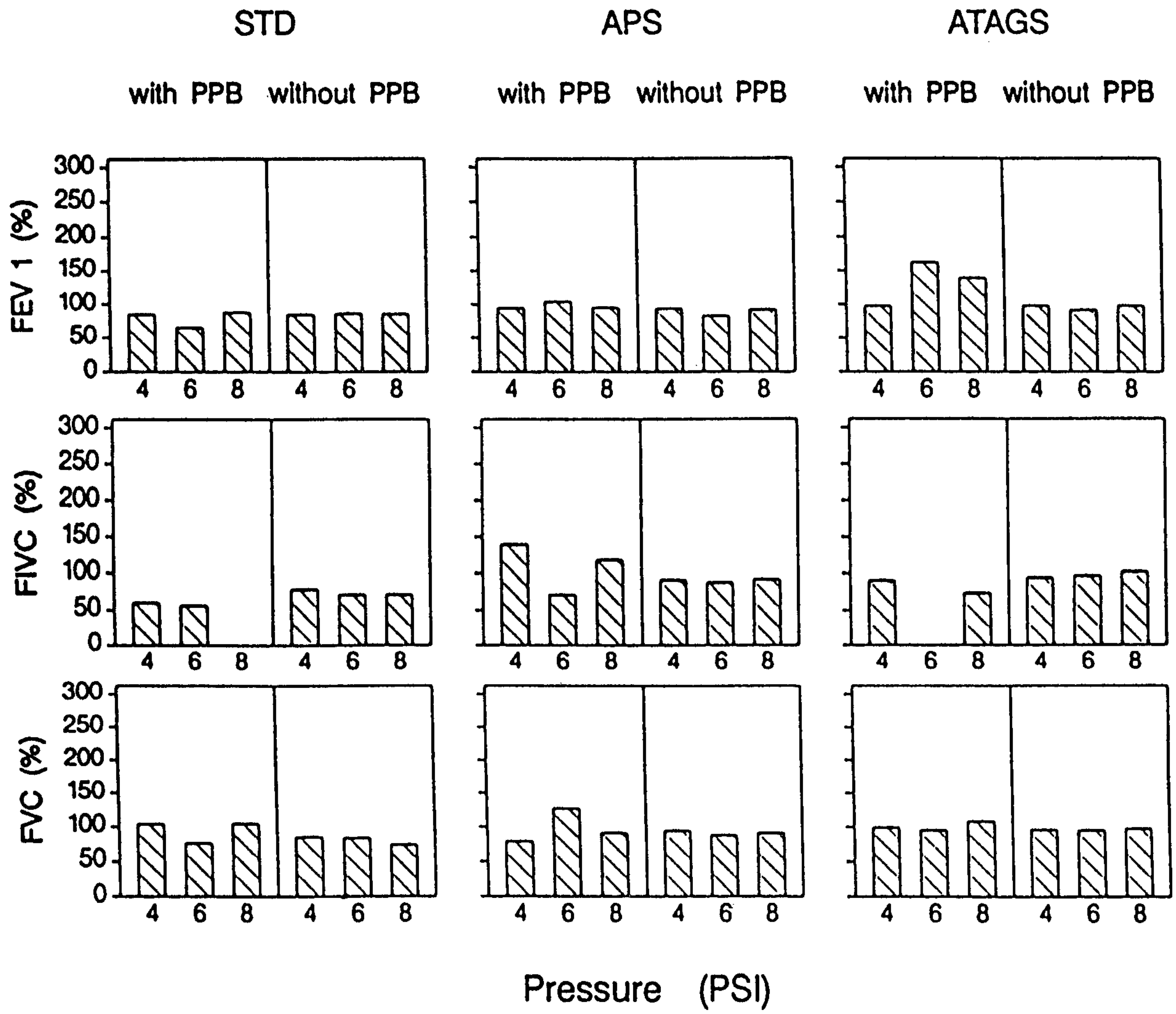

DE
Data is percent of Pre-Baseline

Appendix O
Percent of Pre Baseline for Each G-suit Condition at 4, 6, and 8 psi
Subject HU



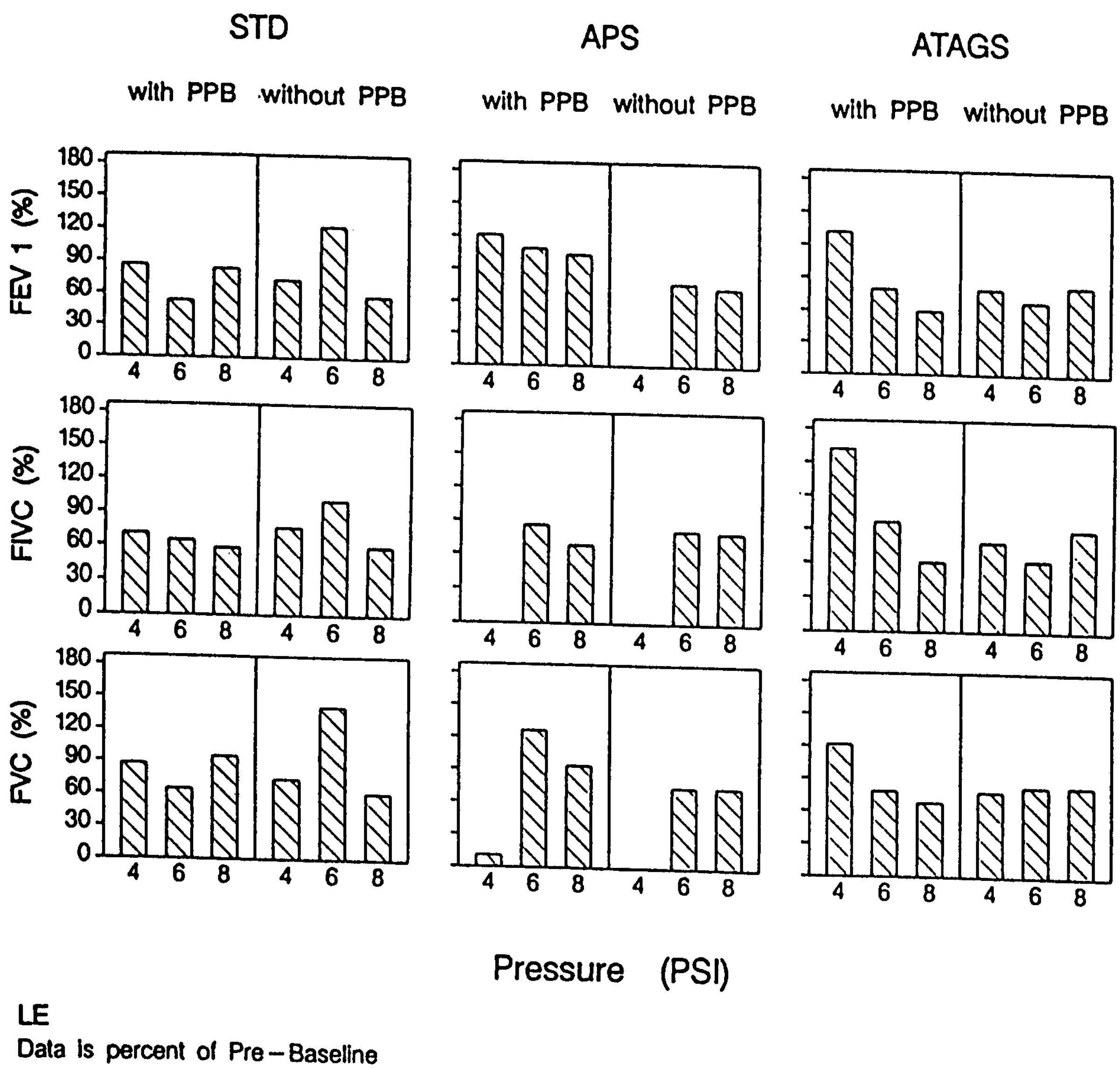

HU
Data is percent of Pre-Baseline

Appendix P
Percent of Pre Baseline for Each G-suit Condition at 4, 6, and 8 psi
Subject KN

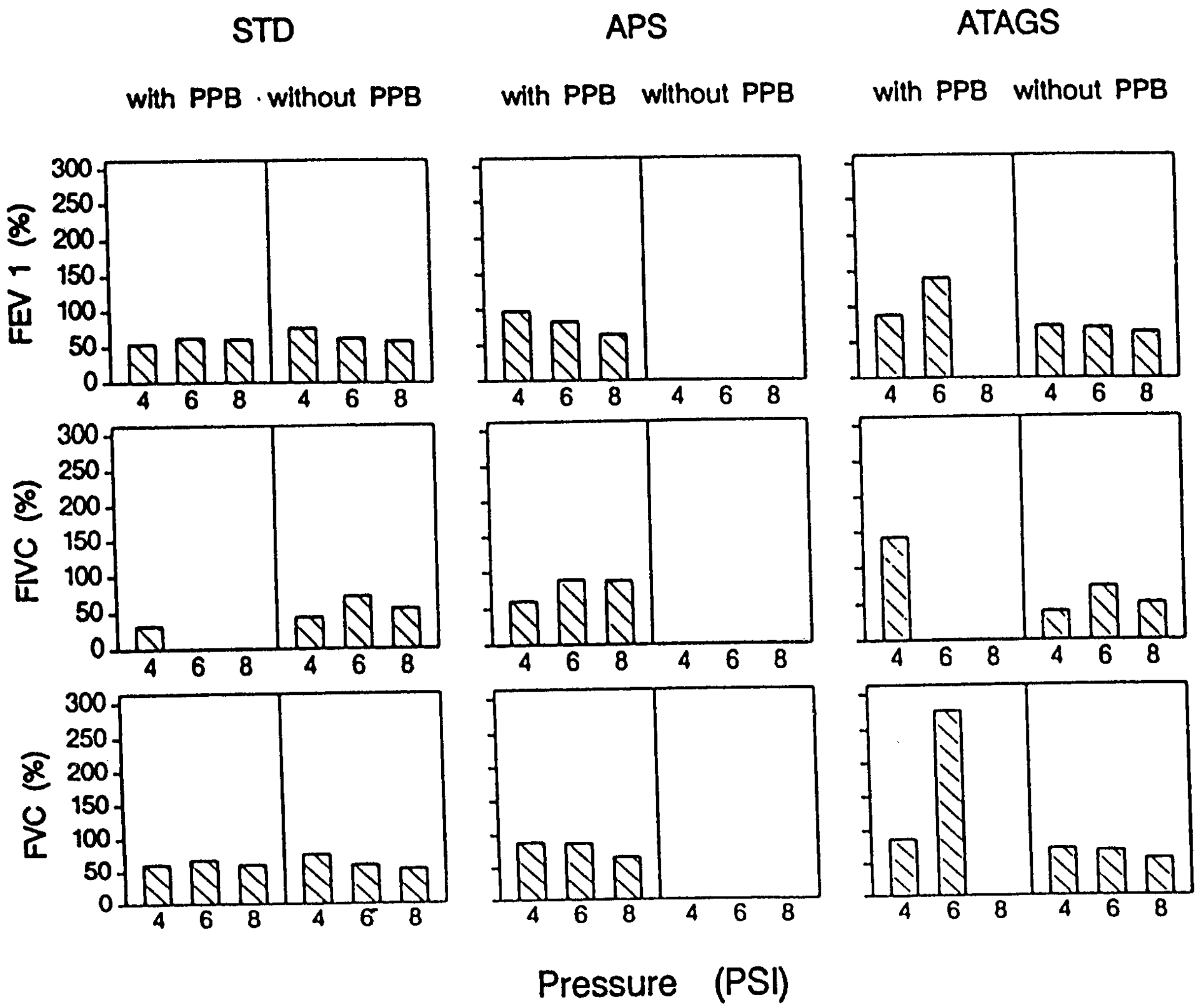



KN
Data is percent of Pre-Baseline

Appendix Q
Percent of Pre Baseline for Each G-suit Condition at 4, 6, and 8 psi
Subject LE

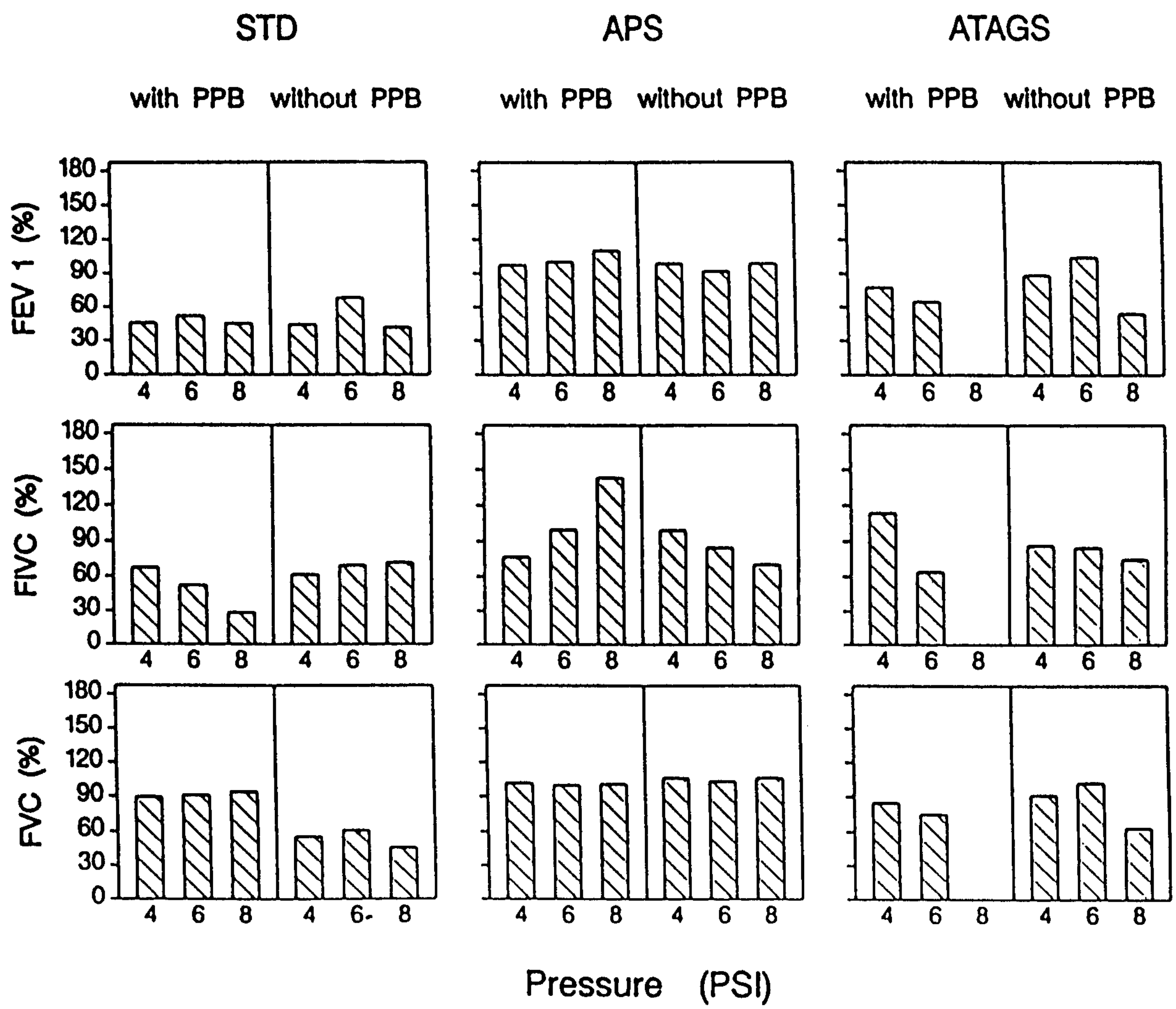


Appendix R
Percent of Pre Baseline for Each G-suit Condition at 4, 6, and 8 psi
Subject NE



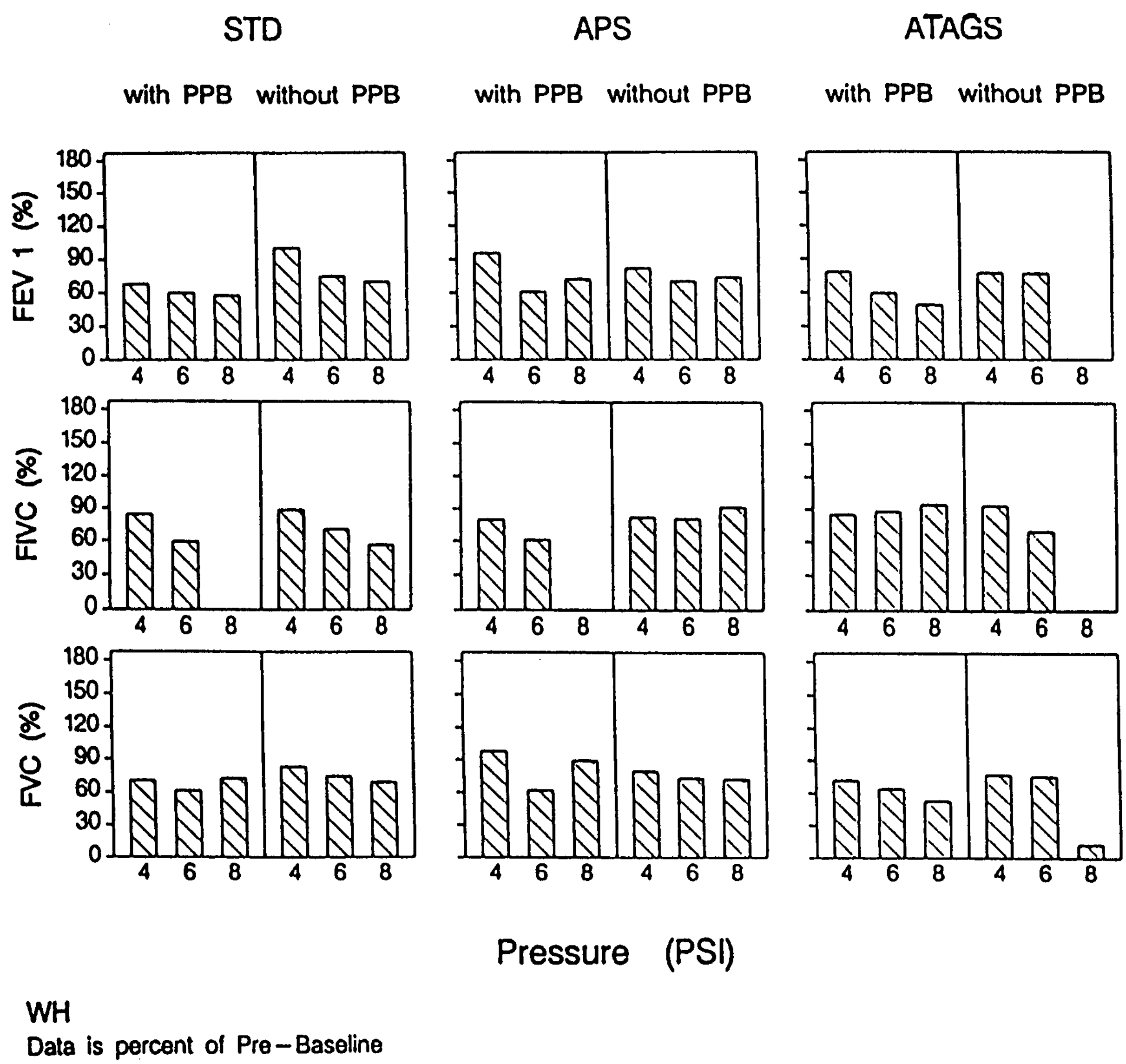

NE
Data is percent of Pre-Baseline

Appendix S
Percent of Pre Baseline for Each G-suit Condition at 4, 6, and 8 psi
Subject SM

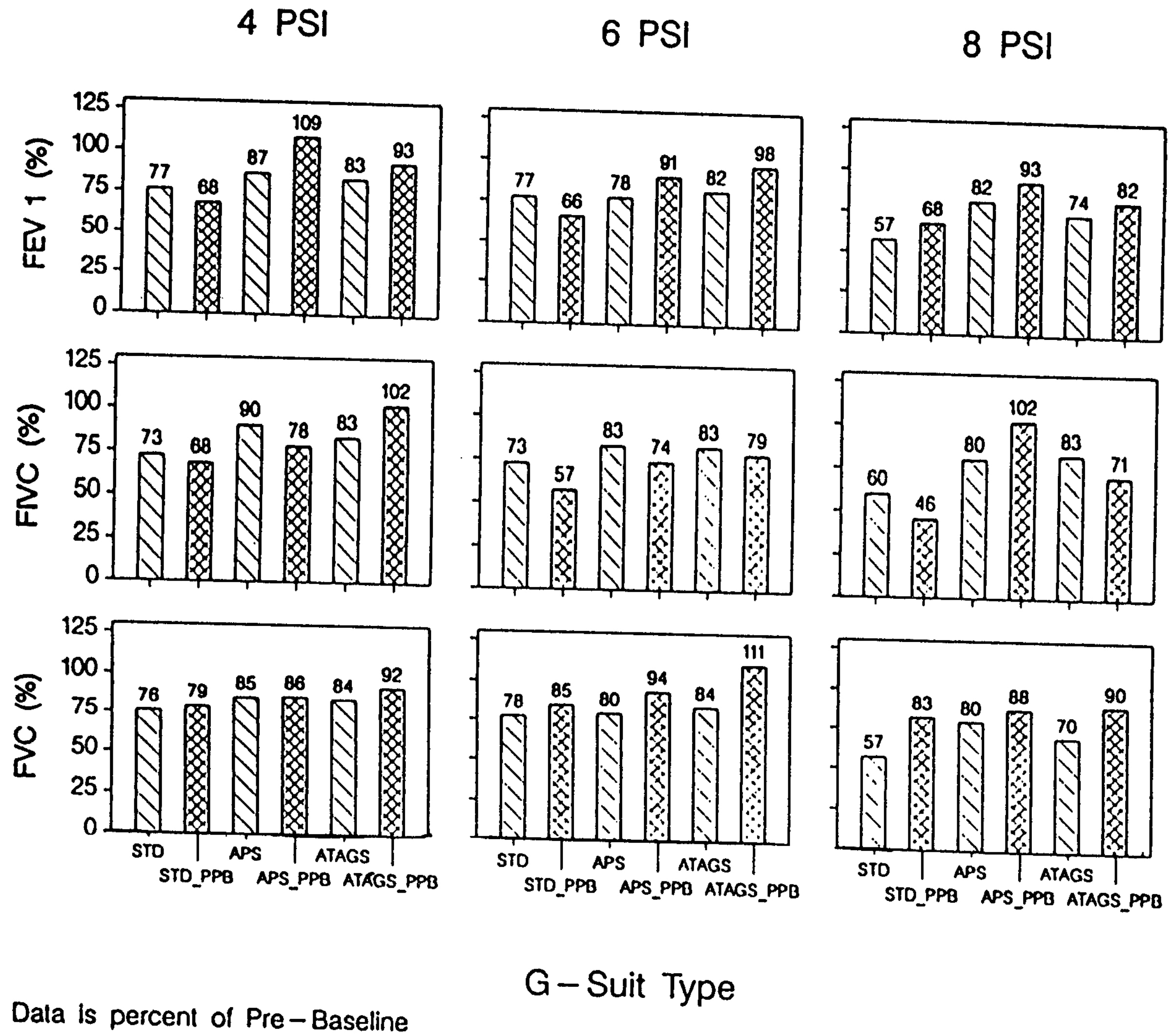



SM
Data is percent of Pre-Baseline

Appendix T
Percent of Pre Baseline for Each G-suit Condition at 4, 6, and 8 psi
Subject WH



Appendix U
Percent of Pre Baseline for Each G-suit Condition at 4, 6, and 8 psi
Average Across All Subjects



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